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**A Biostratigraphic Analysis of Core
Samples from Wells Drilled in the
Devonian Shale Interval of the
Appalachian and Illinois Basins**

Stephen J. Martin and Ronald E. Zielinski

July 14, 1978



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Issued: July 14, 1978

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Abstract

A palynological investigation was performed on 55 samples of core material from four wells drilled in the Devonian Shale interval of the Appalachian and Illinois Basins.

Using a combination of spores and acritarchs, it was possible to divide the Middle Devonian from the Upper Devonian and to make subdivisions within the Middle and Upper Devonian.

The age of the palynomorphs encountered in this study is Upper Devonian.

Biostratigraphy

A palynological investigation was performed on 55 samples of core material from four wells drilled in the Devonian Shale interval of the Appalachian and Illinois Basins. The following wells were investigated: O-1 Well, Christian County, Kentucky; P-1 Well, Sullivan County, Indiana; KY-2 Well, Martin County, Kentucky; and VA-1 Well, Wise County, Virginia.

Using a combination of spores and acritarchs, it is possible to divide the Middle Devonian from the Upper Devonian and to make subdivisions within the Middle and Upper Devonian. A major difference between the Middle and Upper Devonian is found in the sizes of the spores, as well as in the appearances and disappearances of specific genera and species. In North America, Middle Devonian strata are typified by the spores Rhabdosporites langi (and related species), Calamospora atavata, and other spp. In addition to spores, acritarch taxa are very diagnostic of the boundary between the Middle and Upper Devonian. In the Middle Devonian there are often Duvernaysphaera spp, Polyedryxium spp, and numerous species of Multiplicisphaeridium spp.

None of the above taxa, however, were observed in the four wells studied here.

Typical Upper Devonian forms were encountered in all four wells. Quisquiletes buchhornensis was found at the base of the O-1 and KY-2 Wells (samples O-1-4 and KY-2-66, respectively). It is known to be present only in Upper Devonian strata [1]. Also found in the basal parts of some of the studied wells were Multiplicisphaeridium sprucegrovensis, Diexallophasis remotum, Cymatisphaera peiferi, Maharanites spp, as well as many Ancyrospora species (a diagnostic spore for the Frasnian [2]). The age of the lower strata in the P-1 Well is based on the occurrence of acritarchs M. sprucegrovensis, and an unnamed echinate acritarch encountered elsewhere in Frasnian black shales. The age of the basal strata in VA-1 is based on the acritarch taxa D. remotum and M. Sprucegrovensis. The dark spores (indicating a higher thermal maturation and second cycle deposition) in VA-1-27 through VA-1-32 are Middle Devonian (Emsian and Gedinnian), but the acritarchs are definitely of Upper Devonian age as are the lighter colored, less mature (T.A.I.), Ancyrospora-like spores.

Differentiation of the Frasnian and Famennian depends on the disappearance of Ancyrospora-like spores, at the end of the Frasnian, and

the first appearances of taxa-like Vallatisporites pussilites and V. vallatus. Acritarchs also changed markedly over the boundary. Multiplicisphaeridium-like taxa did not extend into the Famennian; however, Veryhachium spp, Uniellum spp, and Micrhystridium spp become dominant. Very small Cymatiosphaera spp are found in the Famennian, while large Cymatiosphaera species (2x to 3x the size of Famennian taxa) were found in the Frasnian. All these taxa were used to obtain the time boundaries in these wells.

Differentiation of the Upper Devonian and Lower Mississippian depends primarily on changes in spores. Acritarch taxa do not change significantly from one unit to the next. The spores seen in the upper strata in the four wells are characteristic of the Upper Devonian (Famennian). The taxa associated with the basal Mississippian, (i.e., Cyrtospora clavigera, Spinozonotriletes uncatus, Endosporites micromanifestus and Knoxisporites literatus) were not found in these wells.

Biostratigraphy summary of the O-1 Well

The four samples from the O-1 Well are Upper Devonian in age. All four contain large amounts of reworked marine algae and small amounts of land derived materials and presumably were deposited under restricted marine conditions.

Age

Sample O-1-1 (depth 2184 ft) was deposited in Upper Devonian (Famennian) time based on several spores. Sample O-1-3 (depth 2261 ft) was deposited in the Upper Devonian because of its stratigraphic

occurrence between samples O-1-1 and O-1-4. There are no diagnostic palynomorphs in sample O-1-3 which could be used to determine the age. Sample O-1-4 (depth 2293 ft) is Upper Devonian (Frasnian) in age based on the occurrences of acritarchs and spores. Sample O-1-5 (depth 2317 ft) is Upper Devonian (presumably Frasnian) based on the similarity to O-1-4. There is insufficient palynomorphs to make a precise age determination.

Environment of deposition

All four samples were deposited in restricted marine environments. The samples were deposited in an area where reworked and partially degraded marine algae (Tasmanites spp) were redeposited. The absence of abundant "freshly" deposited marine algae indicates that there were restrictions to open marine conditions.

Biostratigraphy summary of the P-1 Well

Three samples from the P-1 Well are Upper Devonian in age. The upper part of the section is classified as nonmarine. The restricted marine environment was found in the lower part of the P-1 Well.

Age

Sample P-1-1 (depth 2492 ft) is Upper Devonian (Famennian) in age based on occurrences of pollen, spores and acritarchs. Sample P-1-2 (depth 2521 ft) is Upper Devonian (and probably from near the Frasnian-Famennian boundary) based on limited palynomorphs and on its stratigraphic position between P-1-1 and P-1-3. Sample P-1-3 (depth 2549 ft) is Upper Devonian (Frasnian) in age based on the occurrences of acritarchs and spores.

Table 1 - AGE
O-1 Well

MOUND NO. DEPTH		FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
0-1-1	2184 ft	D	U	FA	Spores: <u>Vallatisporites pusillites</u> Acritarchs: <u>Diexallophasis remotum</u> , <u>Veryhachium trispinosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
0-1-3	2261	D	U	FR-FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
0-1-4	2293	D	U	FR	Acritachs: <u>Quisquiletes buckhornensis</u> , <u>Microhystridium</u> spp	D	I	I	Large size of Tasmanites indicative of Devonian
0-1-5	2317	D	U	FR	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KEY		D Devonian	U Upper	I Indeterminate	FA Famennian	FR Frasnian			

Table 2 - DEPOSITIONAL ENVIRONMENT AND DISTRIBUTION OF PALYNOMORPHS
0-1 Well

		FIRST CYCLE PALYNOMORPHS														SECOND CYCLE PALYNOMORPHS	
		NONMARINE							MARINE								
		RESTRICTED MARINE															
MOUND NO.	DEPTH	NUMBER OF COUNTS	VASCULAR PLANT DEBRIS	MEGASPORES	SPORES WITH GRANULE PROCESSES	SACCATE & ZONATE SPORES	SPORES IN TETRADES	OTHER POLLEN AND SPORES	TASMANITES	LEIOSPHERES & SPHAEROMORPHS	ACRITARCHS	CHITINOZOAMS	SCOLECODONTS	POLLEN AND SPORES	TASMANITES	ACRITARCHS CHITINOZOAMS SCOLECODONTS	
0-1-1	2184 ft	200	2			t		t	12	4	1			1	78		
0-1-3	2261	200	4					t	31	1				1	64		
0-1-4	2293	300	4					t	11	6	1		t	1	79		
0-1-5	2317	300	1					t	1	2					95		

t = trace (less than 1%)

Table 3 - AGE
P-1 Well

MOUND NO.		DEPTH	FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
			SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
P-1-1	2492 ft	D	U	FA	Spores: <u>Vallatisporites</u> <u>pusillites</u> , cf. <u>Spelaeotriletes</u> <u>obtus</u> Acritarchs: <u>Diexallophasis</u> cf. <u>D. absona</u>	I	I	I	Very little organic matter	
P-1-2	2521	D	U	FR-FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian	
P-1-3	2549	D	U	FR	Spores: <u>Spelaeotriletes</u> <u>sp</u> Acritarchs: <u>Multi-plcisphaeridium</u> <u>sprucegrovensis</u> , <u>Ammonidium sp</u> , <u>Diexal-</u> <u>lophasis</u> , cf. <u>D.</u> <u>denticulatum</u>	D	I	I	Large size of Tasmanites indicative of Devonian	
KEY										
D	Devonian	FA	Famennian							
U	Upper	FR	Frasnian							
I	Indeterminate									

Table 4 - DEPOSITIONAL ENVIRONMENT AND DISTRIBUTION OF PALYNOMORPHS
P-1 Well

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS												SECOND CYCLE PALYNOMORPHS		
		NONMARINE						RESTRICTED MARINE						MARINE		
		NUMBER OF COUNTS	VASCULAR PLANT DEBRIS	MEGASPORES	SPORES WITH GRANULE PROCESSES	SACATE & ZONATE-POLEN	SPORES IN TETRADES	OTHER POLLEN AND SPORES	TASMANITES	LEIOSPHERES & SPHAEROMORPHS	ACRITARCHS	CHITINOZOAMS	SCOLECODONTS	POLLEN AND SPORES	TASMANITES	ACRITARCHS CHITINOZOAMS SCOLECODONTS
P-1-1	2492 ft	200	98			t		t	t	2	t			t	t	t
P-1-2	2521	300	t						13	3	t			t	84	t
P-1-3	2549	300	1			t		t	8	6	t		t	t	83	t

t = trace (less than 1%)

Environment of deposition

Sample P-1-1 was deposited in a relatively nonmarine environment. The adjacent land mass contributed large amounts of plant material to the sediment. The influence of land-derived organic material is much less in samples P-1-2 and P-1-3 which are restricted marine deposits. Sample P-1-2 was from a restricted marine environment in which many partially degraded marine algae (Tasmanites spp) accumulated.

Sample P-1-3 was also a site for Tasmanites accumulation.

Biostratigraphy summary of the KY-2 Well

Thirty-three samples from the KY-2 Well are all Upper Devonian in age. The environmental conditions alternated from a marine environment with diverse phytoplankton productivity, to restricted marine conditions with limited diversity and accumulation of reworked algae, and to nonmarine accumulations of abundant plant debris.

Age

Samples KY-2-2 to KY-2-47 (depths of 2444 to 3114 ft) are Upper Devonian (Famennian) in age, based on the presence of diverse and abundant spores and acritarchs.

Samples KY-2-50 to KY-2-66 (depths of 3144 to 3386 ft) are Upper Devonian (Frasnian) in age, based on the presence of diverse and abundant spores and pollen.

Environment of deposition

The environments of deposition shifted continuously throughout the depositional history. Open marine conditions typified

by diverse acritarch floras are found in several samples. Phytoplankton productivity was greater in the restricted marine conditions typified by large numbers of Tasmanites in some samples. In other samples, the abundance of vascular plant debris indicated depositional conditions characteristic of a nonmarine environment.

Biostratigraphy summary of the VA-2 Well

Fifteen samples from the VA-1 Well are Upper Devonian in age. All samples contain large amounts of reworked Lower and Middle Devonian palynomorphs. Except for the deepest sample, the section was predominantly nonmarine.

Age

In sample VA-1-2 (depth 4885 ft) there is insufficient material to make an age determination. Samples VA-1-4 through VA-1-13 (depths of 4915 to 5229 ft) are all Upper Devonian (Famennian) based on the occurrences of pollen, spores, and acritarchs. There is insufficient material in samples VA-1-15 to VA-1-26 (depths of 5259 to 5393 ft) to make age determinations. In samples VA-1-27 to VA-1-32 (depths of 5408 to 5469 ft) the rocks are Upper Devonian (Frasnian) in age, based on the occurrences of acritarchs and spores. In all the samples from the VA-1 Well there are abundant and diverse reworked and degraded spores and acritarchs from Middle and Lower Devonian aged rocks.

Environment of deposition

Sample VA-1-32 (depth 5469 ft) is different from the other fourteen samples in that it was deposited in restricted marine conditions with a minor influx of older plant debris. The succeeding samples VA-1-29 to

Table 5 - AGE
KY-2 Well

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
KY-2-2	2444 ft	D	U	FA	Acritarchs: <u>Micrhystri-</u> <u>dium sp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-4	2475	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-6	2504	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-8	2535	D	U	FA	Spores: <u>Aurospora tri-</u> <u>angulatus</u> Acritarchs: <u>Gorgonispha-</u> <u>eridium ohioense</u> , <u>Very-</u> <u>hachium trispinosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-9	2555	D	U	FA	Spores: <u>Hymenozonotri-</u> <u>letes lepidophytus</u> , <u>H. micromanifestus</u> Acritarchs: <u>Veryhachium</u> <u>trispinosum</u> , <u>Micrhystidium spp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-11	2597	D	U	FA	Spores: <u>Convolutispora</u> <u>sp</u> Acritarchs: <u>Micrhystri-</u> <u>dium sp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-13	2627	D	U	FA	Spores: <u>Hymenozonotri-</u> <u>letes famenniensis</u> Acritarchs: <u>Multiplici-</u> <u>sphaeridium ramusculo-</u> <u>suhe</u> , <u>Gorgonisphaeri-</u> <u>dium ohioense</u> , <u>Very-</u> <u>hachium trispinosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-15	2658	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-18	2688	D	U	FA	Acritarchs: <u>Gorgonispha-</u> <u>eridium ohioense</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-20	2716	D	U	FA	Spores: <u>Convolutispora</u> <u>spp</u> Acritarchs: <u>Micrhystri-</u> <u>dium spp</u>	D	I	I	Large size of Tasmanites indicative of Devonian

KEY

D Devonian
U Upper
FA Famennian

Age
KY-2 Well (Continued)

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
KY-2-21	2745 ft	D	U	FA	Spores: <u>Ancyrospora</u> sp Acritarchs: <u>Michrhystridium</u> spp	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-24	27	D	U	FA	Spores: <u>Ancyrospora</u> sp	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-25	2804	D	U	FA	Spores: <u>Ancyrospora</u> sp, saccate spores Acritarchs: <u>Gorgonisphaeridium ohioense</u> , <u>Veryhachium trispinosum</u> , <u>Michrhystridium</u> spp, <u>Uniellium</u> spp	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-27	2833	D	U	FA	Spores: <u>Ancyrospora</u> spp Acritarchs: <u>Gorgonisphaeridium ohioense</u> , <u>Veryhachium trispinosum</u> , <u>Michrhystridium</u> spp	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-29	2862	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-32	2891	D	U	FA	Acritarchs: <u>Gorgonisphaeridium ohioense</u> , <u>Michrhystridium</u> spp	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-34	2922	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-35	2948	D	U	FA	Acritarchs: <u>Gorgonisphaeridium ohioense</u> , <u>Uniellium</u> spp, <u>Veryhachium trispinosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-38	2978	D	U	FA	Acritarchs: <u>Veryhachium trispinosum</u> , <u>Michrhystridium</u> spp, <u>Multiplicisphaeridium sprucegrovensis</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-40	3006	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian

KEY
D Devonian
U Upper
FA Famennian

Age
KY-2 Well (Continued)

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
KY-2-42	3036 ft	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY2-44	3055	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-45	3085	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-47	3114	D	U	FA	Acritarchs: <u>Senziella incurvata</u> , <u>Veryhachium trispinosum</u> , <u>Michrhystridium spp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-50	3144	D	U	FR-FA	Acritarchs: <u>Multiplicisphaeridium</u> cf. <u>Mu. fisheri</u> , <u>Veryhachium trispinosum</u> , <u>Michrhystridium spp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-51	3171	D	U	?FR	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-54	3201	D	U	FR	Acritarchs: <u>Cymatio-sphaera peiferi</u> , <u>Gorgonisphaeridium sp</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-55	3230	D	U	FR	Acritarchs: <u>Multiplicisphaeridium sprucegrovensis</u> , <u>Maharanites sp.</u> , <u>Mu. ramispinosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-58	3261	D	U	FR	Acritarchs: <u>Cymatio-sphaera peiferi</u> , <u>Diexallophasis remotum</u> , <u>Polydrixium rabians</u> , <u>Mu. ramusculosum</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-60	3288	D	U	FR	Acritarchs: <u>Mu. spruce-grovensis</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-62	3329	D	U	FR	Stratigraphic location, no diagnostic palynomorphs	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-63	3358	D	U	FR	Acritarchs: <u>Quisquiletes buckhornensis</u>	D	I	I	Large size of Tasmanites indicative of Devonian
KY-2-66	3386	D	U	FR	Acritarchs: <u>Quisquiletes buckhornensis</u>	D	I	I	Large size of Tasmanites indicative of Devonian

KEY

D Devonian

U Upper

FR Frasnian

Table 6 - DEPOSITIONAL ENVIRONMENT AND DISTRIBUTION OF PALYNOMORPHS
KY-2 Well

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS												SECOND CYCLE PALYNOMORPHS		
		NONMARINE				RESTRICTED MARINE		MARINE								
		NUMBER OF COUNTS	VASCULAR PLANT DEBRIS	MEGASPORES	SPORES WITH GRAPNEL PROCESSES	SACCATE & ZONATE SPORES-POLLEN	SPORES IN TETRADES	OTHER POLLEN AND SPORES	TASMANITES	LEIOSPHERES & SPHAEROMORPHS	ACRITARCHS	CHITINOZOAMS	SCOLECODONTS	POLLEN AND SPORES	TASMANITES	ACRITARCHS CHITINOZOAMS SCOLECODONTS
KY-2-2	2444 ft	308	5			t		1	23	4	2			1	64	
KY-2-4	2475	320	30					11	34	6	t			3	16	
KY-2-6	2504	300	15			t		5	18	3	t			3	55	
KY-2-8	2535	300	57			4		13	8	4	8			2	3	
KY-2-9	2555	300	60			3		8		14	12			2	1	
KY-2-11	2597	250	24	t		2	1	19	24	7	1			4	17	
KY-2-13	2627	300	65		t	2	t	16	3	6	5			1	1	
KY-2-15	2658	206	22					9	21	1	t			1	47	
KY-2-18	2688	307	13		t			5	37	9	1		t	3	33	
KY-2-20	2716	309	21		1	1		6	42	2	3			7	15	
KY-2-21	2745	301	33	t	t	1		10	31	7	1			9	7	
LY-2-24	2774	301	29		1	3	t	13	39	4	t			2	7	
KY-2-25	2804	300	19		t	8		1	3	17	52			1	1	
KY-2-27	2833	400	52		t	4		15	6	6	10			2	3	
KY-2-29	2862	200	1					4	23	3					69	
KY-2-32	3891	300	11		t	t		1	17	23	39		t	3	6	
KY-2-34	2922	300	3			1		11	32	4	t			t	48	
KY-2-35	2948	200	27			4		20	5	10	26		t	5	2	
KY-2-38	2978	300	5		t			18	18	12	12			13	24	
KY-2-40	3006	300	2		t			10	46	9	t			3	30	
KY-2-42	3036	301	4					3	32	1	1			4	56	
KY-2-44	3055	306	2					2	42	10					46	
KY-2-45	3085	201	2					7	31		5				54	
KY-2-47	3114	309	72			t		12	2	5	4			5	1	
KY-2-50	3144	200	76					3	t	7	t			13		
KY-2-51	3171	310	3			2		7	40	33	t		2	4	11	
KY-2-54	3201	301	24			2		5	24	7	t		2	2	32	
KY-2-55	3230	400	1			1		5	65	13	2	t	t	1	12	
KY-2-58	3261	301	9		t	t		t		48	29			12	1	
KY-2-60	3288	305	12			1		14	15	34	10			5	7	
KY-2-62	3329	300	11			1	t	6	29	7	1			3	40	
KY-2-63	3358	300	10			1		2	17	4	2			10	53	
KY-2-66	3386	301	20			t		t	18	3	3		t	6	51	

t = trace (less than 1%)

Table 7 - AGE
VA-1 Well

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS				SECOND CYCLE PALYNOMORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
VA-1-2	4885 ft	D	U	FA	Stratigraphic location, no diagnostic palynomorphs	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-4	4915	D	U	FA	Spores: <u>Vallatesporites pusillites</u> Acritarchs: <u>Cymateospaera cf. Cy. fistulosa</u>	D or S	I	I	
VA-1-6	4945	D	U	FA	Spores: <u>Convolutispora</u> sp, zonate spore Acritarchs: <u>Gorgonispaeridium winslowi</u> , <u>Veryhachium trispinosum</u> , <u>Uniellum</u> spp	D	I	?G	Spores: <u>Tetraletes senu</u> Cramer, <u>Ambitisporites</u>
VA-1-11	4975	D	U	FA	Spores: <u>Hymenozonotriletes micromanifestus</u> Acritarchs: <u>Uniellum</u> spp, <u>V. trispinosum</u>	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-13	5229	D	U	FA	Spores: <u>Vallatisporites pusillites</u> , <u>Convolutispora</u> sp Acritarchs: <u>Uniellum</u> sp, <u>Veryhachium trispinosum</u>	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-15	5259	D	U	FA	Acritarchs: <u>Uniellum</u> sp <u>Veryhachium trispinosum</u>	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-17	5289	D	U	FA	Acritarchs: <u>Veryhachium trispinosum</u> , <u>Micrhystridium</u> spp	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-18	5319	D	U	?FR-FA	Spores: <u>Ancyrospora</u> sp Acritarchs: <u>Veryhachium trispinosum</u>	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-21	5348	D	U	?FR-FA	Spores: <u>Ancyrospora</u> sp Acritarchs: <u>Veryhachium trispinosum</u> , <u>Micrhystridium</u> spp	D or S	I	I	Spore shapes indicative of Devonian or Silurian

KEY

D	Devonian	I	Indeterminate
U	Upper	S	Silurian
FA	Famennian	G	Gedinnian
FR	Frasnian	E	Emsian

Age
VA-1 Well (Continued)

MOUND NO.	DEPTH	FIRST CYCLE PALYNO MORPHS				SECOND CYCLE PALYNO MORPHS			
		SYSTEM	SERIES	STAGE	RATIONALE	SYSTEM	SERIES	STAGE	RATIONALE
VA-1-22	5349 ft	D	U	?FR-FA	Stratigraphic location, no diagnostic palynomorphs	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-25	5393	D	U	?FR-FA	Stratigraphic location, no diagnostic palynomorphs	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-26	5393	D	U	?FR-FA	Stratigraphic location, no diagnostic palynomorphs	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-27	5408	D	U	FR	Acritarchs: <u>Multiplicisphaeridium sprucegrovensis</u> , <u>Diexallophasis remotum</u> , <u>Microhystridium</u> spp, <u>Veryhachium trispinosum</u>	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-29	5439	D	U	FR	Stratigraphic location, no diagnostic palynomorphs	D or S	I	I	Spore shapes indicative of Devonian or Silurian
VA-1-32	5469	D	U	FR	Spores: <u>Ancyrospora</u> spp, <u>Cymatiosphaera</u> cf. <u>C. parvicarina</u>	D	L	G-E	Spores: <u>Bochotriletes robustus</u> , <u>Cymbosporites serex</u>

KEY

D	Devonian	I	Indeterminate
U	Upper	S	Silurian
FA	Famennian	G	Gedinnian
FR	Frasnian	E	Emsian

Table 8 - DEPOSITIONAL ENVIRONMENT AND DISTRIBUTION OF PALYNOMORPHS
VA-1 Well

MOUND NO.	DEPTH	FIRST CYCLE PALYNOMORPHS												SECOND CYCLE PALYNOMORPHS		
		NONMARINE						RESTRICTED MARINE						MARINE		
		NUMBER OF COUNTS	VASCULAR PLANT DEBRIS	MEGASPORES	SPORES WITH GRAPNEL PROCESSES	SACCATE & FUSATE-POLEN	SPORES IN TETRAIDS	OTHER POLLEN AND SPORES	TASMANITES	LEIOSPHERES & SPHAEROMORPHS	ACRITARCHS	CHITINOZOAMS	SCOLECODONTS	POLLEN AND SPORES	TASMANITES	ACRITARCHS CHITINOZOAMS SCOLECODONTS
VA-1-2	4885 ft	200	84	t		t		t	t	1	t			15		
VA-1-4	4915	200	78			t		t	t	t	t			21		
VA-1-6	4945	310	87			t		t		t	2			13	1	
VA-1-11	4975	313	81			t		t		4	3			12		
VA-1-13	5229	300	67	t		t		t		4	4			25		
VA-1-15	5259	211	71			t		t		1	4			25		
VA-1-17	5289	301	69			t		t		2	5			23	1	
VA-1-18	5319	311	53		t			t		1	1			45		
VA-1-21	5348	200	50		t			t		3	t			48	2	
VA-1-22	5379	200	77						t					18	7	
VA-1-25	5393	200	66											26	5	
VA-1-26	5393	200	47					t	9	3	6			39	1	
VA-1-27	5403	314	74							2				17	2	
VA-1-29	5439	220	66						59	18	t		t	30	6	
VA-1-32	5469	200	10		t									4		

t = trace (less than 1%)

VA-1-2 (depths of 5439 to 4885 ft) were all deposited in an area subject to large influxes of sediments eroded from earlier Devonian rocks. The abundance of Middle and Lower Devonian spores in those 14 samples is so great that there are only a few Upper Devonian spores in some samples. This dominance of reworked material indicates deposition in an area near the source of the Middle and Lower Devonian plant debris. The second cycle palynomorphs were probably transported either by fluvial systems subsequent to terrestrial erosion or by submarine currents subsequent to submarine erosion.

Conclusions

The age of the palynomorphs encountered in shales from the four wells studied is Upper Devonian. Although shale thicknesses varied greatly from well to well, the entire Upper Devonian consisting of Frasnian and Famennian subdivisions appears to be present in all wells. Age determinations were based on excellent to poorly preserved palynomorphs. Scolecodonts (teeth of marine worms) were found in some samples but in numbers too small to be useful for correlation. The most common palynomorphs in the shales are the marine algae Tasmanites spp which are not usable for stratigraphic determinations. Tasmanites spp from these shales are of two kinds: fresh, undegraded fossils which show no evidence of breakdown before their incorporation into the sediments, and other Tasmanites spp (labeled second cycle Tasmanites) which show considerable corrosion and breakdown of their thick body walls. Some have higher Thermal Alteration Indices (TAI's) than the "fresh" Tasmanites.

There is one common and widespread biofacies dominated by Tasmanites. The section encountered in the O-1 Well contains abundant Tasmanites and is classified as restricted marine. The Tasmanites-dominated biofacies is found in the basal part of the P-1 Well, where somewhat restricted marine conditions are indicated.

The upper sample in the P-1 Well (depth of 2492 ft) is an example of the biofacies dominated by land plant debris and is completely different from the underlying strata. Shales from the VA-1 Well (VA-1-29 to VA-1-2) are in the land-plant dominated biofacies. The shales contain large amounts of reworked materials derived from older (Middle and Lower Devonian) strata which had undergone thermal alteration prior to erosion and redeposition. The KY-2 Well contains both of these biofacies plus a third open marine facies not found in the other wells (see cross section). This acritarch dominated biofacies is characteristic of open marine conditions in which acritarchs were diverse and abundant. The algae Tasmanites was not abundant and did not accumulate in the numbers expected in an offshore area of high productivity.

Comparisons of the four wells may be based on the time line drawn at the approximate position of the Frasnian-Famennian boundary. The base of Frasnian time (and the base of the Upper Devonian) is near the bottom of all four wells, but time lines cannot be drawn without location of the youngest Middle Devonian strata. Likewise, the Devonian-Mississippian boundary is probably near the top of all samples from the four wells, but without identification of Lower Mississippian strata, that time line cannot be drawn.

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Appendix A.

Description of palynomorphs

Vascular plant debris: pieces of plant debris $> 20 \mu\text{m}$ identifiable by the pattern of the material.

Megaspores: The female reproductive bodies of heterosporous plants; megaspores are generally greater than $200 \mu\text{m}$ in diameter; most commonly found in nearshore marine, deltaic-transitional, or terrestrial environments.

Spores with Grapnel Processes: spores with hook-like or grapnel shaped processes; commonly found in transitional environments, especially lagoonal sequences; reached maximum taxonomic diversity in the Frasnian.

Saccate and Zonate Pollen and Spores: pollen and spores which are ornamented by inner-tube-like structures surrounding the central bodies or by sacks which entirely enclose the central bodies. The structures supposedly aided in air-borne and/or aquatic dispersal of the pollen and spores.

Spores in Tetrads: most Devonian spores formed in groups of four cells, tetrads, which would break apart before or during dispersal. When large numbers of tetrads are found, terrestrial or transitional environments are suggested.

Other Pollen and Spores: pollen and spores not included in the preceding four categories; all of terrestrial origin and subject to dispersal by wind or water.

Tasmanites: large (to $300 \mu\text{m}$), thick-walled, single-celled marine algae, related to the green algae Chlorophyta

Leiospheres and Sphaeromorphs: very thin-walled marine algae, of spherical shape and variable size.

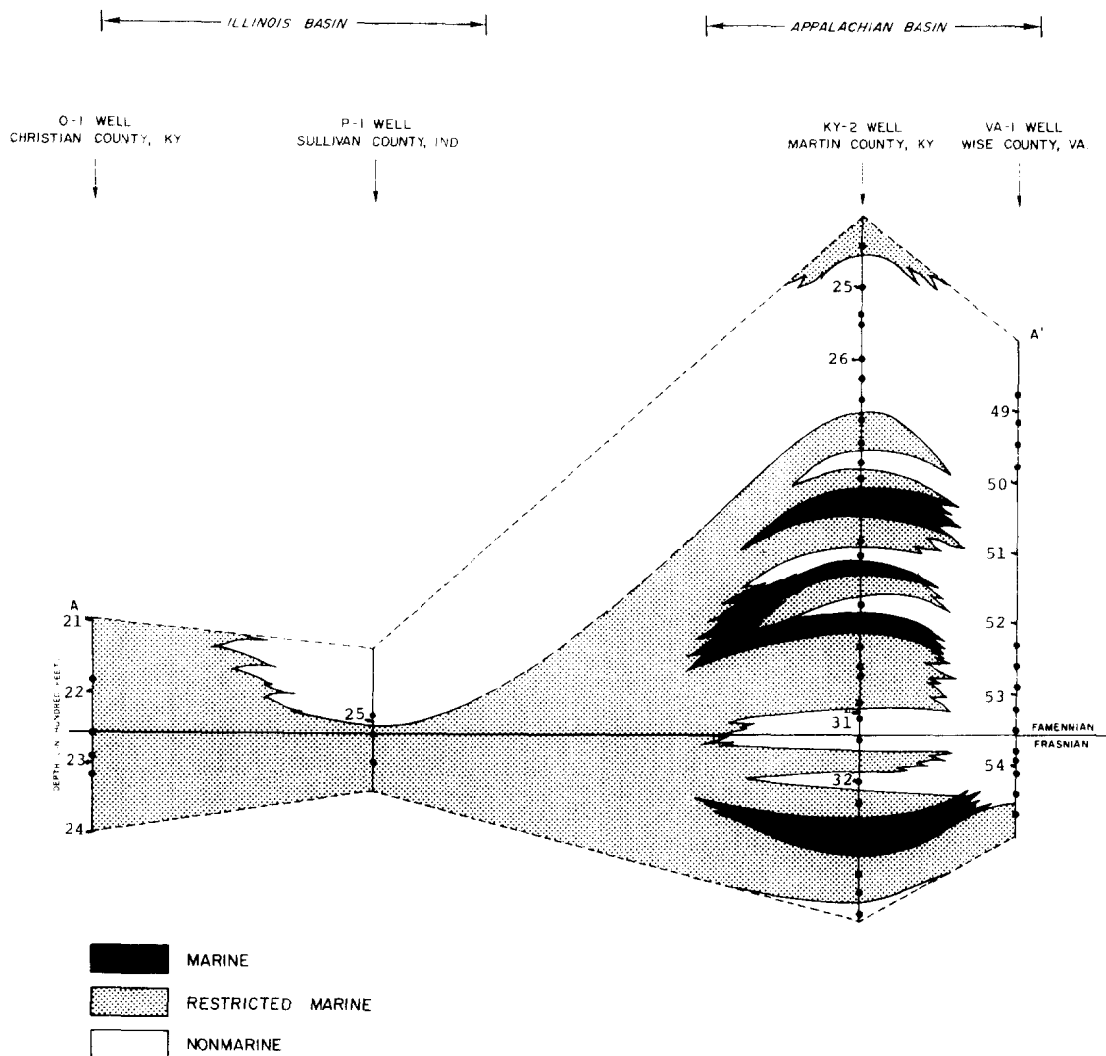
Acritarchs: single-celled cysts of marine algae, distinguished by very fine, detailed geometric forms; known only from marine strata.

Chitinozoans: large, ornate, vase-shaped palynomorphs, of unknown affinities; many workers hold the opinion that they were some part of the life cycle of some animal.

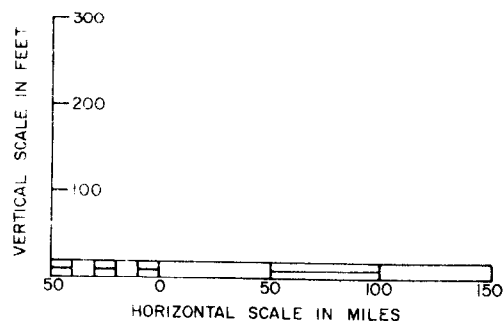
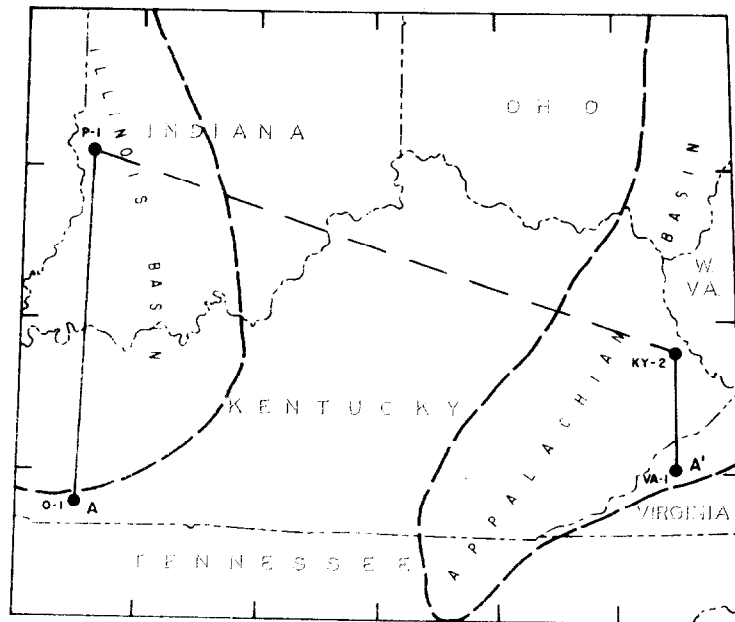
Scolecodonts: teeth of marine, polychete worms.

Appendix B.

SYSTEM	SERIES	STAGE
PALEOZOIC	DEVONIAN	FAMENNIAN
	UPPER	FRASNIAN



LOCATION OF WELLS



EASTERN GAS SHALES
REGIONAL DISTRIBUTION OF AGE
AND DEPOSITIONAL ENVIRONMENTS
SECTION A-A'

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